THE EFFECTS OF SOIL TEXTURE ON SPECIES DIVERSITY IN AN ARID GRASSLAND OF THE EASTERN GREAT BASIN

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Abstract.— A primary factor limiting plant species diversity in desert grasslands seems to be soil texture. Loamy soils consistently support more species than do adjacent sands. This is probably related to the increased micro-environmental differences associated with heavy textured soils. Such soils would be expected to have more micro-topographic and soil moisture variations than sandy soils.

The grassy communities of the Great Salt Lake State Park, situated on the northern end of Antelope Island of the Great Salt Lake, Utah, were intensively studied during the period 14 June to 3 September 1971. This study was part of a larger project funded by the Student Originated Studies Program of the National Science Foundation (Carter *et al.*, 1971). The major aim of my study was to evaluate the relationships of vascular plant diversity to soil texture and micro-environmental variation within the arid grasslands of the park.

The fact that soil texture is an important ecological factor controlling plant populations is well known (Black, 1968). Soil particles regulate the flow of moisture, retention of nutrients, and movement of air within a given soil (Russell, 1957). Locally, extensive work has been done to document characteristics of soils of the Great Salt Lake-Wasatch Front region (Erickson, 1968; Jennings, 1946; Thorne, 1968). Other research in this general geographic area has shown definite correlations between composition of grassland communities and edaphic conditions (Kleiner, 1966 and 1968; Ludwig, 1965 and 1969).

The area under consideration is in the northeastern part of the Great Basin, approximately 30 mi. northwest of Salt Lake City, Utah. The vegetation of the park is dominated by grassland species typical of this region. The communities studied have been grazed by livestock until the recent past and support both native and introduced plant species (Table 1). Soils in the park ranged from sand, at locations near the lake, to sandy loam in areas farther from the shoreline. Since most of the precipitation in this part of the Great Basin is restricted to the winter months, most water available to vegetation is present for only a short time in the spring. The only other sources of water during the year are small, infrequent storms which occur during the drier summer months. Total precipitation annually averages approximately 10 in. Therefore water is one of the primary limiting factors for plants in this area, and competition for water may have important effects on the abundance and distribution of most plant species.

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TABLE 1. Species encountered in the grasslands of Great Salt Lake State Park showing average quadrat frequency expressed as a percentage of the total within the 15 sections of each 16.2 hectare plot.

Species	Plot 1	Plot 2	Plot 3
Agropyron spicatum	0.3	1.0	41.0
Aristida longiseta	13.8	50.5	29.3
Artemisia tridentata	5.0	1.3	0.3
Astragalus utahensis	0.3	0.3	0.3
Bromus tectorum	85.0	99.3	100.0
Castilleja angustifolia	0.3	0.3	0.3
Chrysothamnus nauseosus	1.5	0.3	0.3
Chrysothamnus viscidiflorus	7.3	0.3	0.3
Cleome lutea	0.5	1.0	0.3
Cryptantha parva	0.3	0.3	0.3
Cymopteris longipes	0.3	0.3	10.5
Distichlis stricta	14.0	0.3	0.3
Erigeron englemani	0.3	0.3	3.8
Erodium cicutarium	38.5	91.5	20.8
Festuca myoros	0.3	2.5	0.3
Guterrezia sarothrae	2.8	0.3	0.3
Hordeum jubatum	2.8	0.3	0.3
Lactuca scariola	0.3	0.3	0.3
Lomatium grayii	0.3	0.3	5.5
Oryzopsis hymenoides	3.0	1.0	0.3
Phlox longifolia	8.0	3.0	6.8
Poa sandbergii	15.3	30.3	54.3
Salsola kali	0.5	0.3	0.3
Sisymbrium altissimum	0.3	0.3	0.3
Sitanion jubatum	0.5	0.3	0.3
Sphaeralcea coccinea	21.3	2.0	2.0
Sporobolus airoides	6.8	0.3	0.3
Sporobolus cryptandrus	8.8	18.3	4.8
Stipa comata	3.5	5.5	0.3
Zigadenus paniculata	0.8	0.3	0.3
Percent exotics	51.3	61.4	42.7
Percent native	48.7	38.6	57.3
Average Plant Diversity/.007 h	3.5	4.2	3.9

METHODS

Three areas in the park were selected for vegetational studies. The first was comprised primarily of introduced species, the second was intermediate with approximately equal numbers of introduced and native species, and the third was dominated by native species. Each area encompassed 16.2 hectares (40 acres) and was subsampled by fifteen 0.007 hectare (1/60 acre) circular sections. Within each of these sections, the vegetation was sampled with 25 quadrats. Each quadrat had an area of 0.25 m^2 and was subdivided into 4 units (quartiles) of equal size. At each sampling point the presence or absence of individual plant species was noted for each quartile. From these quadrat analyses a frequency of occurrence was established for each plant species present.

Soil and surface environmental analyses were made within each of the 0.007 hectare sections. Soil data taken included particle size, pH, free carbonates, and salinity. Soil particle size was determined using Bouyoucos's (1962) method, pH was obtained with a dual glass electrode meter (Leeds and Northrup) on a soil paste, and presence of free carbonates was determined by an effervescence test using a 10 percent HCL solution. Salinity was evaluated by conductivity of soil paste using a Wheatstone Bridge and soil cup electrode. Surface environmental variables such as surface rock, living cover, and bare soil were determined quantitatively by an ocular estimation technique (Warner and Harper, 1972). Average values for the several variables are reported for the three major study areas in Table 2.

Using MacArthur and Wilson's (1967) diversity index

$$\text{Diversity index} = \frac{1}{\Sigma P^2_{a-z}}$$

where $$P_a = \frac{\text{frequency of species a}}{\Sigma \text{ frequency of species a-z}}$$

it was possible to calculate a workable diversity index for each of the study sections. The minimum diversity for this index is 1.0 and the magnitude of the index increases as the number of species and the uniformity of their frequency values increase.

Results and Discussion

The influence of various environmental parameters on plant species diversity was evaluated by stepwise multiple regression (Dixon, 1969). Results of the computer analysis give an indication of the relative influence of each environmental variable on vegetational diversity (Table 3). It is apparent that of those environmental variables studied, soil texture has the most influence upon plant diversity. The relationship between soil texture and plant diversity is graphically shown in Fig. 1. This is probably due to a greater degree of microenvironmental diversity on more consolidated soils. Increased diversity might be related, for example, to more small scale runoff and accumulation of water on the heavier textured soils. Additionally, in an arid environment one might expect "effective"

Table 2. Average values for environmental variables/16.2 hectare plot.

	Plot 1	Plot 2	Plot 3
Percent sand	83.4	62.4	63.4
Percent fines	16.6	37.6	36.6
pH	8.34	7.53	7.34
Conductivity*	2235	1391	dna†
Percent surface rock	1.1	4.9	31.3
Percent living cover	73.8	64.8	52.4
Percent surface litter	15.1	16.8	9.0
Percent bare soil	15.6	17.0	14.4
Carbonates (No. of 0.007 hectare sections found in)	13	7	9

*Conductivity in ohms is measurement of salinity
†dna = data not available

precipitation (i.e., precipitation which can be utilized by plants) to be lower on heavier textured soils due to less deep infiltration and correspondingly larger losses via evaporation as opposed to trans-

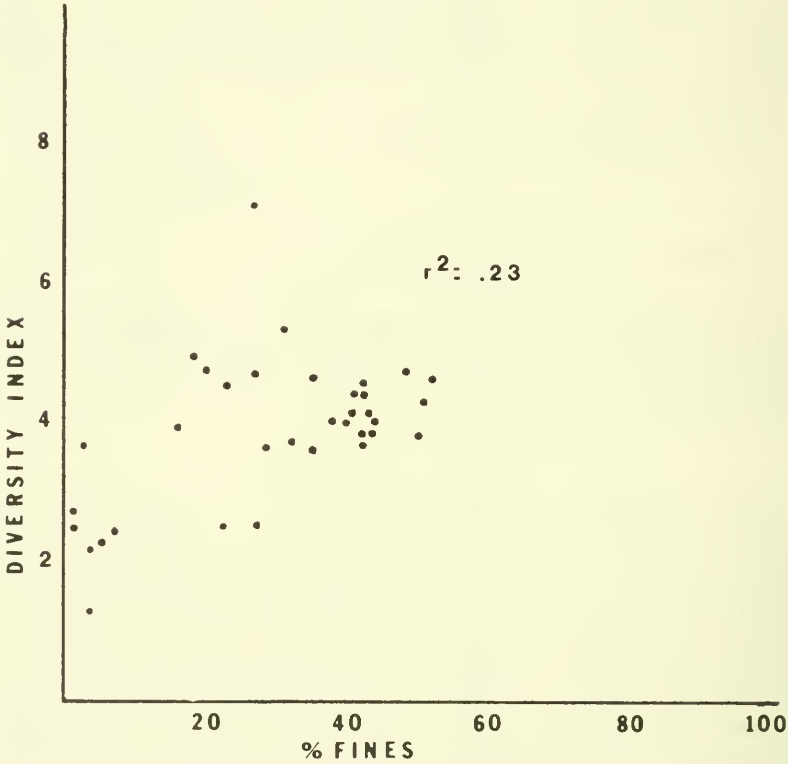

Fig. 1. Graphical portrayal of the relationship between plant diversity and percentage of soil particles classified as fines (percent silt + percent clay). Diversity indices are calculated using MacArthur and Wilson's (1967) index as described in text.

Table 3. Results of stepwise multiple regression analysis of environmental variables affecting plant species diversity. Variables are shown in the order in which they entered the analysis.

Variable	Influence on Diversity	R-value	R-square value	Increase in R-square
Soil fines	+	.4796	.2301	.2301
Surface litter	+	.5383	.2898	.0597
Living cover	—	.5743	.3298	.0400
Free carbonates	—	.6231	.3882	.0584
Soil sand	—	.6440	.4148	.0266
Bare soil	+	.6532	.4267	.0119
ph	—	.6552	.4292	.0025
Salinity	—	.6580	.4330	.0037

piration (Black, 1968). The combined effects of heterogeneous distribution of water and greater aridity of heavy textured soils per unit precipitation would result in more habitat diversity (niches) and a more sparse vegetation with the likelihood of reduced competition between individuals. Both conditions could lead to enhanced diversity. Data supportive of these hypotheses can also be extracted from Ludwig's (1969) study of several grassland communities in northern Utah (Table 4).

TABLE 4. Community data for grasslands in northern Utah (Ludwig, 1969).

Community type	Average no. spp./.025 acre	Average no. spp./quad	Average percent fines
Agropyron spicatum	26.28	5.80	69
Stipa comata	13.74	4.44	36
Sporobolus cryptandrus	10.29	4.61	30
Oryzopsis hymenoides	9.67	3.12	—

CONCLUSIONS

In Great Salt Lake State Park, sandy sites consistently have lower diversity than loamy sites. These data suggest that much of the vegetational diversity within the community is dependent upon edaphic factors; this finding is probably related to the uniform environment of sandy areas. On such sites, the best adapted species could invade and completely dominate, whereas in areas which foster microenvironmental diversity (i.e., heavier textured soils, which have more small scale runoff and therefore small adjacent areas with very different amounts of "effective" precipitation) any one species would find it difficult to dominate the entire area.

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